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New Developments in the Study of Surface Coatings for Titanium Implants

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Abstract: *Dental defects and loss are one of the most important categories of diseases in clinical dentistry. With the improvement of people's living standards and the perfection of material technology, the use of implants to restore missing teeth has become a major trend. Titanium is the main body of the implant, and titanium and titanium alloy implants still face the risk of prolonged osseointegration or poor bonding and eventual failure in clinical applications. Therefore, in recent years, many researchers have tried to create coatings on the surface of titanium and titanium alloy implants in order to obtain faster and stronger implant-bone bonding, reduce the risk of implant failure and increase the clinical success rate.*

Keywords: *Titanium; coating; dental implants*

1. Introduction

In the 1850s Branemark implanted optical speculums made of titanium into the tibia and fibula of rabbits in vivo microscopic observation[1]. At the end of the experiment,the implanted speculum was firmly bonded to the surrounding bone tissue and could not be removed;Branemark called this phenomenon osseointegration and began to study the use of this phenomenon. Since then, titanium implants have been widely used in the dental field for their excellent biocompatibility,high mechanical strength and corrosion resistance. In the early 1940s, Bothe et al. first introduced titanium into the medical field,until 1910 when pure titanium implants were created. However,the metallic nature of the surface of pure titanium implants has led to clear boundaries in the integration with bone tissue,which has led to the use of different surface bioactive coatings on titanium implants in order to achieve an ideal surface structure in harmony with the natural bone tissue microenvironment.

This article will review such methods. Titanium (Ti)has excellent mechanical strength,fracture toughness,corrosion resistance,low modulus of elasticity and good biocompatibility,which makes it a superior material for biomedical applications such as dentistry and orthopaedics. However,at present titanium implants are still subject to graft integration failure or implant-centred infections[2]. In order to achieve better implant biomaterials,surface modifications of titanium implants have been carried out in recent years using three approaches:physical,chemical and biological,all of which have the central objective of improving the biological embedding between implant and bone and reducing bacterial adhesion on the surface of titanium implants.

2. Antibacterial coatings

To date, once a mature bacterial biofilm has formed on the implant surface,no treatment modality has been able to completely remove it. Once a mature bacterial biofilm has formed on the implant surface,no treatment can completely remove it. Therefore,an important prevention strategy is to make the implant surface antimicrobial and prevent the formation of biofilms. Depending on the antimicrobial composition of the implant coating,antimicrobial coatings can be classified as follows.

2.1 Antibiotic and organic antimicrobial coatings

Currently broad-spectrum antibiotics(3-lactams,macrolides,etc.)are widely used for implant coatings. The mechanism ofaction of conventional antibiotics is to inhibit the cell wall and protein synthesis of microorganisms and to interfere with DNA transcription and translation. Fluorine(F),zinc(Zn),calcium (Ca),copper(Cu),cerium (Ce),chloride (CI)and iodine (I)ions can be loaded onto the titanium-based metal surface by anodic oxidation[3]. The antibacterial mechanism of ionic coating may be:(1)metal cations adsorbed on the surface of bacterial cell membrane,causing the orderly and tightly packed bacterial cell membrane to become disorganized and scattered,disrupting the inherent function of the cell membrane;(2)generation of reactive oxygen species to oxidize with the bacterial cell membrane,increasing the permeability of the cell membrane;(3)free ions are absorbed by the bacterial cell membrane,and are combined with proteins and nucleic acids containing sulfhydryl (-SH),amino(-NH)and carboxyl (-COOH)groups in the cytoplasm. Liu et al. compared pure titanium with titanium-copper implants in vitro experiments and found that titanium-copper alloy had stronger antibacterial activity against Streptococcus mutans and Porphyromonas gingivalis,and cell proliferation and adhesion tests using mesenchymal stem cells showed that titanium-copper alloy had similar biocompatibility to pure titanium.

2.2 Natural compounds for coating

The natural compounds used for coating are mainly polysaccharides and flavonoids. Chitosan(CS) is a bactericidal polysaccharide with low toxicity and high biodegradability. The CS coating was found to inhibit the proliferation of Staphylococcus aureus in bacterial adhesion experiments. In vitro experiments by Valverde et al. found that HA CS coated titanium reduced the adhesion and inhibited the growth of S. aureus.

2.3 Physical and chemical coatings on titanium implants

The main physical and chemical coatings on the implant surface are titanium paste coatings,hydroxyapatite(HA)coatings,polypyrrole coatings,ceramic coatings,etc. using PSP,anodic oxidation,MAO and other surface addition methods,and SLA coatings using SLA,absorbable media grinding and other surface reduction methods[4] . SLA coatings are the most commonly used surface modification technique,usually involving surface roughening of titanium implants with silica,aluminium trioxide,iron trioxide,etc. at a voltage of around 120 V,followed by acid etching with hydrochloric acid,nitric acid,hydrofluoric acid,etc. After SLA treatment,a primary rough surface of 10-50 um pores and a secondary rough surface of 1 to 3 um micro-pores were formed on the implant surface,similar to natural bone traps which stimulated osteoblast differentiation and proliferation and enhanced osseointegration[5] . The SLA treatment was also found to produce a thin layer of titanium oxide on the surface of titanium implants,increasing the alkali hydrogen content and promoting homogeneous nucleation of calcium and phosphorus deposits,resulting in higher bioactivity of the implant,a significantly higher rate of surface osteoblast proliferation,shorter bone healing time and reduced treatment time for implant restoration[6] . However,this method also suffers from residual metal contamination of the surface,insufficient hydrophilicity and poor bond strength,which affects the long-term stability and success rate of the implant[7] and limits further applications.

3. HA coatings

HA coatings, like SLA coatings,are widely used in the field of oral implantology. HA is a calcium phosphate-based ceramic with a similar chemical composition and organisation to bone tissue,which is chemically bonded to the bone tissue by HA is a calcium phosphate ceramic with a similar chemical composition andorganisation to bone tissue.

3.1 Application of HA coatings

HA coatings are applied to the implant surface using sol-gel, PSP, on-beam assisted deposition, laser and biomimetic methods[8]. HA coatings enhance the biological activity of the titanium metal, stimulate osteoblast division and proliferation, enhance osseointegration and meet the required mechanical properties of the implant, which can withstand high occlusal forces [8-9]. Clinical application studies have confirmed that HA-coated implants are effective in reducing peri-implant bone resorption, preventing and reducing the biological width of the gingiva and preventing peri-implantitis, but HA-coated implants prepared by the current process also have the disadvantages of low bond strength, dissolving too quickly and residual stresses that cannot be eliminated[9] . At the same time, the porous surface and the good bioactivity of HA coatings are also conducive to the adhesion and proliferation of pathogenic bacteria, resulting in the absorption, disintegration or disappearance of the coating,which is detrimental to the long-term results of implant restoration[10].

3.2 Glass-ceramic coatings

Glass-ceramic coatings are superior to HA coatings in terms of mechanical strength, are not harmful to humans, have good biocompatibility and are more firmly bonded to bone tissue. More importantly, the glass-ceramic coating can regulate the coefficient of thermal expansion and bioactivity of the coating, which is conducive to the formation of a strong bond with titanium metal He Dingyong et al [11]produced AP40 glass-ceramic coatings on titanium substrates by the PSP technique and found that the crystallinity of the ceramic coatings was significantly improved after heat treatment, and the bond strength between the ceramic and metal was also significantly improved. Under scanning microscopy, the coating was homogeneous and dense with reduced porosity[12] . It is a typical bioresorbable and degradable material that precipitates calcium and phosphorus ions after degradation, which is beneficial to the formation of new bone tissue and can be used as an ideal bone tissue material. However,the rate of degradation of glass-ceramic coatings is higher than the rate of new bone production in vivo, which does not create a balance between osteogenesis and osteolysis [13],limiting the popularity and application of B-TCP.

4. Facilitating osseous coating

There are two general ways to promote osseointegration of implants. increase the ability of osteoblasts to adhere, proliferate and differentiate, and the second is to control inflammatoryThe former is more commonly studied. The former has been studied more. The former has been studied extensively.

4.1 Biological Factor Coatings

The most studied proteins are bone morphogenetic proteins (BMPs), intravascular. The most studied proteins are bone morphogenetic proteins (BMPs), vascular endothelial growth factor (VEGF), and vascular endothelial growth factor (VEGF). The most commonly studied biokines are bone morphogenetic proteins (BMPs), vascular endothelial growth factor (VEGF). The most common proteins are bone morphogenetic proteins (BMPs), vascular endothelial growth factor (VEGF), fibroblast growth factor (FGF), transforming growth factor β (FGF) and other proteins. fibronectin (FN) and growth differentiation factor (GDF). BMPs are released from osteoblasts, platelets and endothelial cells and deposited in the bone matrix. BMPs are released from osteoblasts, platelets and endothelial cells and deposited in the bone matrix. The main components of the BSP are: alkaline phosphatase (ALP), collagen type I (COL-I) and bone sialoprotein (BSP). BMP-2 has strong pro-osteogenic and osteoprogenitor cell aggregation and induces the expression of bone sialoprotein (BSP). BMP-2 has a strong ability to promote the aggregation of osteoprogenitor cells and induce their osteogenic differentiation[14].

4.2 Extracellular matrix and biopeptide coatings

The extracellular matrix is a complex network of complex network of macromolecules that can recruit mesenchymal stem cells and support their differentiation. Molecules in the extracellular matrix include COL-I, hyaluronic acid and chondroitin sulphate, etc. COL-I is an important component of the bone. The titanium-based implants coated with hydroxyapatite (HAP) and COL-I were implanted in New Zealand rabbits[15]. The titanium-based implants coated with hydroxyapatite (HAP) and COL-I were implanted in New Zealand rabbits. A study by Ao et al. [16] found that in a rabbit femoral defect model, COL-I + HA titanium ,the COL-I + HA titanium coating increased the rate of integration of the implant into the surrounding bone and prevented aseptic loosening of the implant.

5. Conclusion

In summary, the coating of inorganic and organic components that mimic natural bone tissue can directly influence the proliferation and differentiation response of the peri-implant tissue. The addition of organic components is beneficial in improving the formation of new bone. However, there are still many problems and challenges in applying them in the clinical setting. The surfaces of current clinical implants have no nerve or vascular attachments and are not biologically active. The use of suitable techniques to modify the surface with organically active factors that promote vascularity, nerve and osteogenesis is still one of the directions for the future development of implants. Therefore, organic-inorganic composite coatings may form a true bone-like coating, promising a new generation of implants with excellent functional and biological properties. The ideal coating material should prevent peri-implant tissue infection, enhance initial stability and meet processing requirements. tissue infection, enhance the initial stability of the implant . the ideal coating material should prevent peri-implant tissue infection, enhance the stability of the implant during the initial implant placement and meet the feasibility of processing. The various types of implant surface coatings that have been reported so far. There are still unresolved issues and more in-depth studies are in progress. At the same time, the majority of studies are still limited to in vitro and animal studies. There is a lack of attempts at implantation in the jaw. In order to assess more comprehensively how the coating affects the prognosis, and how the coating affects the prognosis of the implant, more in-depth studies are in progress. The study of implants is also needed in order to more fully assess how the coating affects the prognosis and the risk factors of the coating in practice. A comprehensive clinical evaluation of the implants is needed in order to more fully assess how the coating affects the prognosis and the risk factors of the coating in practice. A targeted selection of implant coatings with performance advantages is possible.

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